The Use of Ceramic as a Substitute for Aggregate

By

Mohamad Naqiudin Zainudin

16814

Dissertation submitted in partial fulfillment of the requirement of the

Bachelor of Engineering (Hons)

(Civil Engineering)

MAY 2015

Universiti Teknologi PETRONAS,

32610 Bandar Seri Iskandar,

Perak Darul Ridzuan, Malaysia

CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Civil Engineering Programme
Universiti Teknologi PETRONAS
in partial fulfillment of the requirement for the
Bachelor of Engineering (Hons)
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Approved by,

____

Ir. Dr. Ibrahim Kamarudin

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

MOHAMAD NAQIUDIN ZAINUDIN

ABSTRACT

Ceramic exist in various form throughout our daily life, ceramic are widely known by average human as tiles, pots, art-ware, dinnerware, pottery, brick and toilets. These products are normally referred to as customary or silicate-based ceramics. Whilst the conventional of ceramic product are being used and innovate over the years, other component of ceramic which are also being used in advanced technology such as space shuttle tile, engine components, artificial bones and teeth, computers and other electronic components and cutting tools, just to name a few. Thus, ceramic are non-metal which are highly in demand in both industry and conventional use for daily activity.

ACKNOWLEDGEMENT

First and foremost, I would like to gratitude to those who helped me with my research. Thank you for those who lend me their hand and support throughout my entire research.

I owe my deepest gratitude to the one and Only Allah S.W.T for bestowing his blessing during this paper production.

Thank you to my supervisor as he help me to guide and lead the path for this research to be done. His guidance and knowledge are well appreciated. His supervision has helped me a lot throughout this two semester.

Special thanks I contributed to the lab technician which helped me to prepare my sample, providing sufficient materials, apparatus and PPE. Thank you also for guide me throughout my research with the manual and lesson they taught me.

Furthermore, thank you to all my friends who helped me a lot in finishing this paper. Without them, the research will not be completed by time. Thanks to Aishah, Ammar and my other friends who contribute a lot in this paper.

Last but not least, thanks to my beloved family who always be there for me, for giving me advise and support me morally. They provide me with spirit for me to endure this research and not giving up easily.

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CHAPTER 1

INTRODUCTION

1.0 INTRODUCTION

Chemical definition

Ceramic can be fit to defined as inorganic, non-metallic materials that are basically comprised of clays and minerals from the earth.

Ceramic in nature are crystalline forms and considered as compound which consist of metallic and non-metallic elements. Elements which present in the ceramic compound are such as aluminum and oxygen (alumina – Al_2O_3), silicon and nitrogen (silicon nitride – Si_3N_4), silicon and carbon (silicon carbide – SiC), etc.

Advantage of ceramic

Ceramics are better by comparison of weight than metals, the weight are usually 40% lesser than conventional metal which are widely used in aircraft, missile and spacecraft application to conserves fuel. Other than that, advanced lightweight ceramic are used as a material in gas turbine engine for the rotor to accelerate rapidly compared to metal type rotor because it has less inertia in result of its own weight. Furthermore, they are tend to withstand the oxidation and corrosion process occur in the surroundings as well as chemical reaction in highly contaminated space.

The fact that ceramic has high capability of storing heat, it is widely used in compartment which deal with extreme temperature. Some modern ceramics could withstand 1600 °C compare to high grade super alloy which could only hold heat approximately up to 1100 °C.

Ceramics physical properties are basically low in friction coefficient, high in compressive strength which make them exceptionally hard and are high integrity in wear resistance. Due to this positive characteristic, their interest are particularly in mechanical parts of without the usage of lubricants in the mechanism.

Ceramics are in better placement than metallic material as it is cheaper and abundant in country which has clayey mineral type of soil. Malaysia soil are basically clayey soil which contribute in high production of ceramic material and vast usage of ceramic in construction sector which help to reduce other material in the same categories with high in cost and less in production.

Asphalt road

Asphalt is a mixture of aggregates, binders and fillers used for the flexible road pavement. It is made in mass production accordingly via batching system to control the quality for every production, in single production, it can achieve 800 tons per hour and temperature averaging from 150 ° C to 190 ° C. For the aggregates, crushed rock, sand, gravel or slags are basically used and the binder for the aggregates are bitumen which present naturally in oil entrapment and at asphalt lake in US. Bitumen are mostly used as a binder in order to bind the aggregates into a cohesive mixture. Most design of flexible pavement road structure includes unbound and bituminous-bound materials. This criteria give the road structure to distribute load evenly before it arrives at the formation level.

Physical Properties

The physical properties of aggregates are those that refer to the physical structure of particles that make up the aggregate. The properties including:-

Absorption, Porosity, and Permeability

The inside pore characteristics are very important properties of aggregate particles. The size, the number, and the continuity of the pores through an aggregate particle may affect the strength of the aggregate, abrasion resistance, surface texture, specific gravity, bonding capabilities, and resistance to freezing and thawing action. Absorption relates to the particle's ability to absorb water into particles. Porosity is a ratio of the volume of the pores to the total volume of the particle. Permeability refers to the particle's ability to allow water to pass through. If the aggregates pores are not connected, it may have high porosity and low permeability.

Surface Texture of Aggregates

Surface texture is the pattern and the relative roughness or smoothness of the aggregate particle. Surface texture plays a big role in developing the bond between an aggregate particle and a cementing material. A rough surface texture gives the cementing material something to grip, producing a stronger bond, and thus creating a stronger hot mix asphalt or Portland cement concrete. Surface texture also affects the workability of hot mix asphalt, the asphalt requirements of hot mix asphalt, and the water requirements of Portland cement concrete. Some aggregates may initially have good surface texture, but may polish smooth later under traffic. These aggregates are unacceptable for final wearing surfaces. Limestone usually falls into this category.

Dolomite does not, in general, when the magnesium content exceeds a minimum quantity of the material.

Strength and Elasticity

Strength is a measure of the ability of an aggregate particle to stand up to pulling or crushing forces. Elasticity measures the "stretch" in a particle. High strength and elasticity are desirable in aggregate base and surface courses. These qualities minimize the rate of disintegration and maximize the stability of the compacted material. The best results for Portland cement concrete may be obtained by compromising between high and low strength, and elasticity. This permits volumetric changes to take place more uniformly throughout the concrete.

Density and Specific Gravity

Density is the weight per unit of volume of a substance. Specific gravity is the ratio of the density of the substance to the density of water. The following chart illustrates these relationships for some common substances.

Typical Values		
Substance	Specific Gravity	Density (lb/ft^3)
Water	1.0 (73.4 °F)	62.4 (73.4 °F)
Limestone	2.6	165 to 170
Lead	11.0	680 to 690

Table 1.1: Relationship between Specific Gravity and Density of certain substances

The density and the specific gravity of an aggregate particle is dependent upon the density and specific gravity of the minerals making up the particle and upon the porosity of the particle. These may be defined as follows:

1) All of the pore space (bulk density or specific gravity)
2) Some of the pore space (effective density or specific gravity)
3) None of the pore space (apparent density or specific gravity)

Determining the porosity of aggregate is often necessary; however, measuring the volume of pore space is difficult. Correlations may be made between porosity and the bulk, apparent and effective specific gravities of the aggregate. As an example, specific gravity information about a particular aggregate helps in determining the amount of asphalt needed in the hot mix asphalt. If an aggregate is highly absorptive, the aggregate continues to absorb asphalt, after initial mixing at the plant, until the mix cools down completely. This process leaves less asphalt for bonding purposes; therefore, a more porous aggregate requires more asphalt than a less porous aggregate. The porosity of the aggregate may be taken into consideration in determining the amount of asphalt required by applying the three types of specific gravity measurements, the bulk specific gravity includes all the pores, the apparent specific gravity does not include any of the pores that would fill with water during a soaking, and the effective specific gravity excludes only those pores that would absorb asphalt. Correlation charts and tables provide guidance to asphalt quantities or acceptability of the aggregate.

Aggregate Shape and Surface Texture

Particle shape and surface texture are important for proper compaction, deformation resistance, HMA workability and PCC workability. However, the ideal shape for HMA and PCC is different because aggregates serve different purposes in each material. In HMA, since aggregates are relied upon to provide stiffness and strength by interlocking with one another, cubic angular-shaped particles with a rough surface texture are best. However, in PCC, where aggregates are used as an inexpensive high-strength material to occupy volume, workability is the major issue regarding particle shape. Therefore, in PCC rounded particles are better. Relevant particle shape/texture characteristics are:

i. Particle shape

   Rounded particles create less particle-to-particle interlock than angular particles and thus provide better workability and easier compaction. However, in HMA less interlock is generally a disadvantage as rounded aggregate will continue to compact, shove and rut after construction. Thus angular particles are desirable for HMA (despite their poorer workability), while rounded particles are desirable for PCC because of their better workability (although particle smoothness will not appreciably affect strength) (PCA, 1988).

ii. Flat or elongated particles.

   These particles tend to impede compaction or break during compaction and thus, may decrease strength.

iii. Smooth-surfaced particles.

These particles have a lower surface-to-volume ratio than rough-surfaced particles and thus may be easier to coat with binder. However, in HMA asphalt tends to bond more effectively with rough-surfaced particles, and in PCC rough-surfaced particles provide more area to which the cement paste can bond. Thus, rough-surface particles are desirable for both HMA and PCC.

Mechanical Properties

Mechanical properties of aggregates are important, especially when the aggregate is to be used in road construction where it is subjected to high wear. It is generally understood that the compressive strength of pavement layer cannot significantly exceed that of the major part of the aggregate contained therein, although it is not easy to determine the crushing strength of the aggregate itself. The required information about the aggregate particles has to be obtained from indirect tests, such as crushing strength of prepared rock samples, crushing value of bulk aggregate, and performance of aggregate in road pavement layer. The aggregate crushing value (ACV) test is prescribed by different standards, and is a useful guide when dea1ing with aggregates of unknown performance. Toughness can be defined as the resistance of aggregate to fai1ure by impact, and it is usual to determine the aggregate impact value of bu1k aggregate based on BS standard . Toughness determined in this manner is related to the crushing value, and can, in fact, be used as an alternative test. Hardness, or resistance to wear, is an important property of concrete used in roads and in floor surfaces subjected to heavy traffic. The aggregate abrasion value of the bulk aggregate is assessed using Los Angeles abrasion machine. The Los Angeles Abrasion test combines the processes of attrition and abrasion, and gives results which show a good correlation not only with the actual wear of the aggregate in concrete but also with the compressive and flexural strength of concrete when made with the same aggregate.

1.2 PROBLEM STATEMENT

The study of Ceramic Waste has been carried by previous researcher which focus on reducing the amount of ceramic based waste in landfill by converting the waste to a product used in construction field. Research has been carried out to consider the possibility of using recycled waste as a road base or sub base course in conjunction to provide a better option for the use of construction and demolition (C & D). Many of the research stressed on the usage of ceramic in concrete and the properties it carry in the form of compressive strength, moisture content, and porosity of the material. Nataatmadja and Tan tested the resilient responses of a subbase material with four different type of recycled aggregates. They found that subbase material made from the normal aggregate and recycled aggregate was comparable.

This research is also stressed on the using of conventional and industrial type of ceramic waste to generate economical and environment friendly construction material in part of highway structure due to it abundant source in waste disposal landfill.

There is positive feedback gain from previous researches of using this material as an alternative in construction field. These result on more discussion and researches about the material in different field of work such as an aggregate in concrete and in pavement design. The tendency of developing this material as substitution of conventional one are in high stake and there is an opportunity for this upcoming research to have a bright future in construction industry if turns out better.

In term of cost effective, it is far more better that conventional which are hardly to manufactured in process making it inappropriately expensive. Ceramic are mostly abundant source in Malaysia which comprise of clayey soil. This clayey soil are turn into Kaolin in chemical process of burning to harden the matrix structure of the material. Moreover, kaolin are far more cheaper to process due to its natural condition which are in the state of sedimentary soil rather than granite which need complex process to excavate the rock and process it to smaller size aggregate to make it more convenient.

1.3 OBJECTIVES

- Identify the physical properties of ceramic material.
- Determine the compressive strength of the material with addition of ceramic waste
- To compare the porosity of the sample with the porosity of the conventional asphalt road (excluding porous asphalt).

1.4 SCOPE OF STUDY

(Ramon et al., 2013) Based on previous study and researches on Recycled Ceramic Waste (RCW), the main objective of the research is to observe the feasibility of using stoneware and ceramic from industrial waste as constitutional material in asphalt mixtures. These research basically study the future of this material as in treatment of the waste in presents proportionally with natural aggregate in the asphalt mixture design.

Kruger and Solas, (2013) state that the research on use of bigger ceramic aggregate were reduce. More studies and research focus on the usage of the RCW on the road surface coarse due to its high degree of whiteness and hardness. (Ramon et al., 2013) wrote that the need of the ceramic coarse aggregate are use in road surface are because it will greatly improve sunlight reflection and high quality of hardness help to improve the stability of the road surface. He added in his researches that from the characteristic shows from the ceramic properties will lower the chance of deformation and loss of stability of the surface road due to the axel load from the passing vehicle.

CHAPTER 2
LITERATURE REVIEW

2.1 LITERATURE REVIEW

Sample for the material can be obtained from waste of ceramic industry and from preselected masonry waste such as bricks and tiles or from masonry materials demolished concrete or mortar elements. The resulting aggregate to be recycled maybe stone, ceramic or a mix of cement-base and ceramic elements with debris such as wood, plastic, glass, etc.(Silva J. et.al.,2010)

(Zohrabi M & Karami. S,2010) State that there has been alternative use of aggregate for researches and studies purpose in the past few years which focus on slag from iron and steel blast furnace, foundry sand, china clay and sand, sintered household waste, reclaimed asphalt pavement, recycled concrete, construction and demolition waste, recycled glass, plastic waste and crushed ceramics.

In his article (Koyuncu H et al., 2014), he state that there is some proven researches which specifically focus on the usage of recycle waste aggregate in construction of landfills sub-based road on secondary road, concrete blocks, and manufactured of concrete. But, there is some research basically on Hot Mixed Asphalt eventhough they are not large in numbers.

Using crushed recycled ceramic waste for base course mixture which consider the mechanical properties and the leaching behavior of the aggregate. Van de Van et al. (2011) use 15% of recycled ceramic aggregate (RCA) with the conventional aggregate and result in positive feedback for both mechanical properties and leaching behavior. The drawback of the experiment was decrease in Marshall Stability about 13% and small piece of ceramic detach and fall out from the sample proving that there is lack of adhesion between ceramic – asphalt.

Knights, (1998) concluded that the workability trend of mortar with recycled aggregate (MRA) is decline for recycle ceramic aggregate compare to conventional mortars, in addition if the proportion of ceramic to natural aggregate in the mixture are quite large. In the article of Miranda and Selmo (1999) and Levy and Helene (1997), greater water retention in MRA with ceramic aggregate rather than MRA with aggregates from mortars and concrete.

For bulk density of mortar which use recycled ceramic shows lower value than from using conventional mortars due to high porosity in the ceramic. Miranda and Selmo (1990) state that the value get from MRA with use of ceramic aggregate are lesser than MRA with aggregate from concrete but higher than those of MRA from mortars. While Levy and Helene (1997) research shows that the value for MRA with ceramic are higher compared to both MRA with concrete and mortar.

The increased of shrinkage of ceramic MRA in conjunction to higher water demand compared to conventional aggregate are further explained by (Kikuchi et al., 1998). In the article, Melman et al., (1999) added that parameters such aggregate bulk density, porosity of the adhering mortar and level of saturation effect the degree of shrinkage of the MRA. In the research, Kikuchi et al. (1998) reported that 40% substitution of the ceramic aggregate with the natural one in the mortar sample will increase the shrinkage of MRA compared to the constant sample with no ceramic aggregate added. But the 40% ceramic substitution of aggregate also has lower shrinkage of MRA at the initial stages.

Based on the JKR manual on flexible road design, the structure should consist of subbase course, base course, binder course and wearing course. As if there is more than two layer of binder course, the lower one should act as binder course and the top one is considered as intermediate course. Each layer define its own function as will describe below.

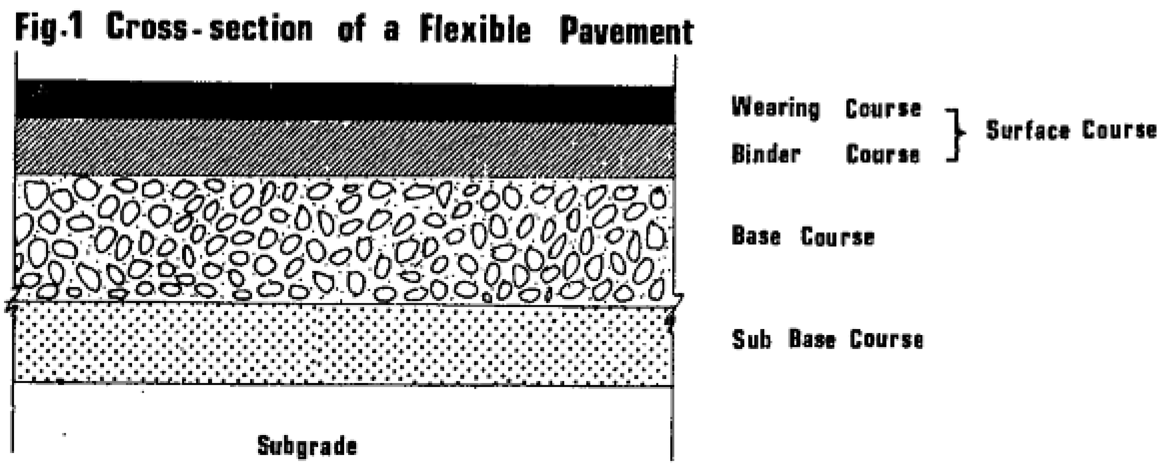
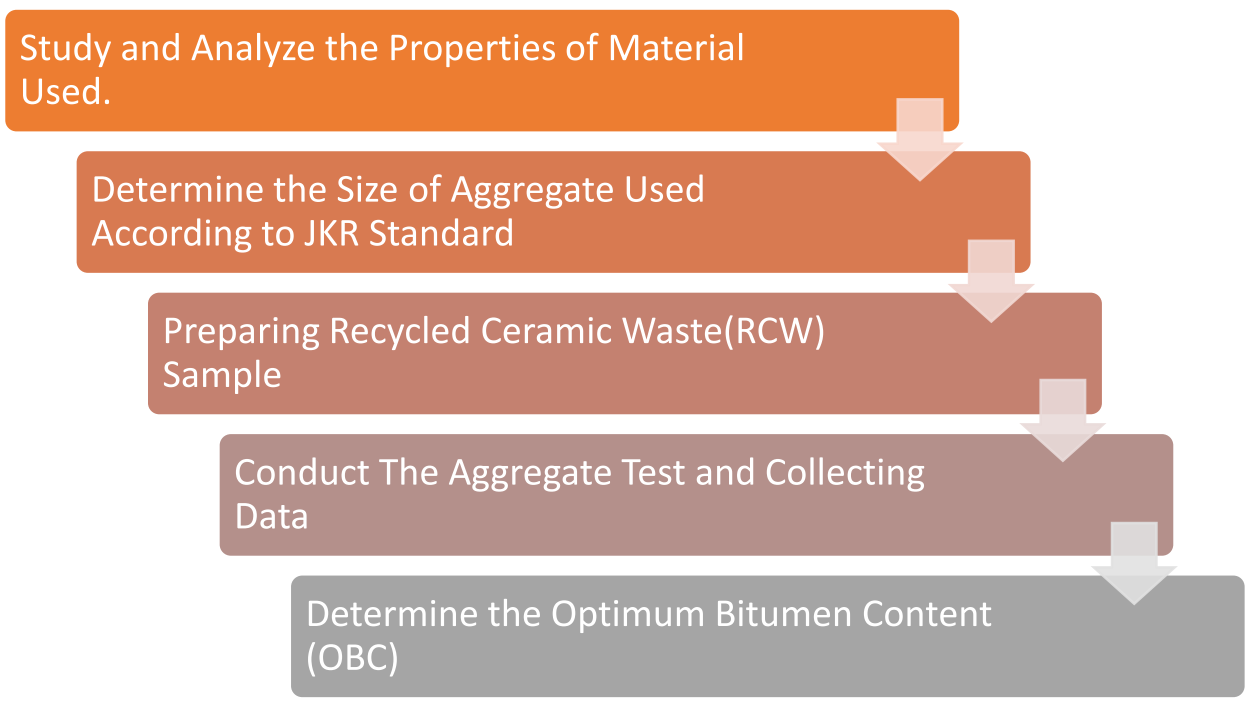


Figure 2.1 Cross Section of a Flexible Pavement

Subgrade layer is the uppermost part of soil (natural or imported), supporting the load from the overlaying structure. Subbase course is layer which consist of special material built up required to specific thickness immediately overlaying the subbase course. This layer disperse the load from base course before it reach to subgrade layer. Subbase sometimes are absent in certain design depends on the type of soil or subgrade of certain site. Base course are also design to specific thickness with special type of material for the structure. This layer plays a prominent role in dispersing and support the traffic load coming from above ground. Surface course consist of binder coarse, intermediate course and wearing course which are impermeable and a flexible lining of road layer.

CHAPTER 3
METHODOLOGY

In conjunction to achieve desire objective, a project plan has been execute to manage the flow of the project to make sure that the target result is accomplished. Several different experimental test has to conduct to get the result, the result then will be interpret in relative to listed component to prove that the experiment are done in controlled environment and according to the standards that already being set by the trusted authority (ASTM). This methodologies show the sequences of the project from the beginning until the end of the experiment. It will be the guide for the practitioner particularly myself to execute the experiment in appropriate manner.



Flowchart of methodology

The material that are being test for this experiment are recycled ceramic waste which are vastly present in construction site, ceramic industry waste and demolition site. From the raw material received, the test subject are crushed to specific aggregate size to follow the standard specification of aggregate size of Jabatan Kerja Raya (JKR). The recycled ceramic were crushed manually by using hammer. The size samples for recycled concrete aggregates and natural aggregates used for this study and 10mm – 20mm. The physical and mechanical properties of the recycled concrete aggregates and natural aggregates were determined by conducting standard tests on the specimens of the aggregates. The aggregate tests are:

i. Specific Gravity and Water Absorption Test
ii. Flakiness Index and Elongation Index
iii. Sieve Analysis
iv. Los Angeles Abrasion Test
v. Aggregate Impact Value Test

BS Sieve Size (mm)	Percentage Passing by Weight			
	A	B	C	D
37.5	100	100	100	100
12.5	45-47	55-85	60-100	-
4.75	30-60	35-65	50-85	55-90
2.00	20-45	25-50	40-70	40-70
0.425	15-30	15-30	25-45	20-50
0.075	8-20	8-20	8-20	8-25
The particle size shall be determined by the washing and sieving method of BS 1377				

Table 3.1: Standard Specification of Aggregate Size of Jabatan Kerja Raya (JKR).

3.1 SPECIFIC GRAVITY AND WATER ABSORPTION TEST

The main purpose of this test is to determine the bulk and apparent specific gravity and absorption of the aggregates particles after 24 hours soaking in the water.

Equipment and Apparatus:

i. Oven
ii. Soft Absorbent Cloths
iii. Airtight Container
iv. Electronic Balance
v. Pycnometer
vi. Hairdryer
vii. Sample Trays
viii. Glass Vessel

Procedure:

i. 1 kg of aggregate sample has been used. The sample is been thoroughly washed on the sieve to remove finer particles, particularly clay, slit and dust.

ii. The prepared sample is been immerse in water in the glass vessel at 20 ± 5°C for 24 ± 0.5 hours. After the immersion period, remove air entrapped on, or bubbles on the surface of the aggregate. Then the vessel is overfilled by adding water and slide the plane ground glass disc over the mouth so as to ensure that no air is trapped in the vessel. The vessel then has been dry on the outside and weighed. (

iii. Then the vessel is emptied and allowed the aggregate to drain while the vessel is refilled with water, sliding the glass disc into position as before. The vessel is dried on the outside and been weighed (

iv. Next, the aggregate is placed on a dry cloth and gently surface-dry it with the cloth. The weigh is recorded

v. The aggregate is placed in the shallow tray in the oven at a temperature of 105 ± 5°C for 24 ± 0.5 hours. Then it been cooled in the airtight container and weighed. (Mass D)

vi. Calculate particle densities as follows:

$$\text{Particle density on an oven-dried basis} = \frac{D}{A-(B-C)}$$

$$\text{Particle density on a saturated and} = \frac{A}{A-(B-C)}$$

$$\text{Apparent particle density} = \frac{D}{D-(B-C)}$$

$$\text{Water absorption (\% of dry mass)} = \frac{D}{A-(B-C)}$$

The mean results shall ne reported for each form of particle density determined. The values of particle density shall be reported to the nearest 0.01 and those for water absorption to the nearest 0.1%.

3.2 FLAKINESS INDEX AND ELONGATION INDEX TEST

To determine the flakiness and elongation of the aggregates

Equipment:

i. Riffle Box
ii. Ventilated Oven
iii. Test Sieves
iv. Electronic Balance
v. Metal Thickness Gauge
vi. Metal Length Gauge

Procedure: (Flakiness Index)

i. Take sufficient quantity of aggregates such that a minimum number of 280 pieces of any fraction can be tested.
ii. Sieve the aggregates first in IS sieve 63 mm and collect the aggregates passing through this sieve and retained on IS sieve 50 mm. Let it be w1 g.
iii. Pass the above aggregates though the 33.90 mm slot of thickness gauge.
iv. Collect the aggregates which are passing in the gauge in a separate tray.
v. Repeat the same procedure for the remaining sample of aggregate according to the table given below.
vi. Weigh the aggregate passing through the various slots of the thickness gauge and let it be W.
vii. Calculate the flakiness index which is taken as the total weight of material passing the various slots of the thickness gauge expressed as a percentage of the total weight of sample taken.

Procedure: (Elongation Index):

i. Take sufficient quantity of aggregate such that a minimum number of 200 pieces of any fraction can be tested.

i. Sieve the aggregates through 80 mm IS sieve and collect the sample passing 890 mm and retained on 40 mm and weigh them accurately. Let it be w1 g.
ii. Pass each and every piece of aggregate from the above sample through the 81.0 mm slot of the length gauge.
iii. Collect the aggregates that are retained in a separate tray.

iv. Repeat the same procedure for the remaining aggregate according to the table given below.
v. Calculate the elongation index that is taken as the total weight of material retained on the various slots of the length gauge expressed as a percentage of total weight of material sample taken.

Flakiness Index Calculation:

$$\text{Flakiness Index} = \frac{\text{Total Passing}}{\text{Total Passing + Total Retained}} \times 100$$

Elongation Index Calculation:

$$\text{Elongation Index} = \frac{\text{Summation of fractions}}{\text{No of fractions}} \times 100$$

3.3 SIEVE ANALYSIS

Objectives

Analyse of a sand and aggregate and presenting the resulting data.

Equipment

1. Riffle box
2. Set of Sieve
3. Sieve Shaker
4. Electronic shaker

Procedure:

1. From the stock-pile of approximately 10 kg aggregates sample out approximately 2 kg of the aggregate using riffle box. Weight the aggregate to the nearest gram. For fine aggregates (sand), sample out approximately 500 g of sand using riffle box from a 2 kg stock-pile. Weight the sand to the nearest o.1 gram.
2. Place the stack of sieves in a mechanical sieve shaker and sieve for 5 to 10 minutes, depending on an initial visual inspection of the probable difficulty involved and quantity of material. Note that if the entre stack of sieves will not fit into the mechanical shaker, perform a shaking operation by hand until the top few sieves can be removed from the stack; place the remainder of the stack in the mechanical shaker.
3. Remove the stack of sieves form the shaker and obtain the weights and compare with the weight obtained in Step 1. This is to detect any loss of material in the mechanical sieving operation. A loss of more than 2 percent by weight of the residue weight is considered unsatisfactory and the test should be repeated.
4. Compute the percent passing each size
5. Make a semilogartihmic plot of grains size versus percent passing.

3.4 LOS ANGELES ABRASION TEST

To determine the aggregates abrasion value in order to evaluate the difficulty with which aggregates particles are likely to wear under attribution from traffic.

Equipment:

i. Los Angeles Abrasion Machine

ii. Steel Ball Abrasion Charges (12 Steel Balls)

iii. 4.75mm and 1.18mm test sieves

iv. Electronic Balance

Procedure:

i. Approximately 5 kg of coarse aggregate retained is placed on the No.4 ASTM sieve (4.75 mm) into the Los Angeles abrasion machine.

ii. 12 steel balls of 44-48 cm in diameter and weight 390-445 g each was feed in as an abrasion charges.

iii. The machine is been turn on and let he drum rotate at 30-33 rpm for 500 revolutions.

iv. Pass the aggregate through No.12 ASTM sieve (1.18 mm) and weigh the material passing this sieve.

v. Determine Los Angeles abrasion value as follow:

$$\text{Los Angeles abrasion value} = \frac{M_2}{M_1} \times 100\%$$

vi. The result is reported to the nearest 0.1.

3.5 AGGREGATE IMPACT VALUE TEST

To determine the toughness of aggregate due to impact

Equipment:

i. Impact Testing
ii. Machine
iii. Cylinder Metal
iv. Tamping Rod
v. Sieve 12.5mm,10mm,2.36mm
vi. Electronic Balance
vii. Oven

Procedure:

The test sample consists of aggregates sized 10.0 mm 12.5 mm. Aggregates may be dried by heating at 100-110° C for a period of 4 hours and cooled.

i. Sieve the material through 12.5 mm and 10.0mm IS sieves. The aggregates passing through 12.5mm sieve and retained on 10.0mm sieve comprises the test material.
ii. Pour the aggregates to fill about just 1/3 rd depth of measuring cylinder. Compact the material by giving 25 gentle blows with the rounded end of the tamping rod.
iii. Add two more layers in similar manner, so that cylinder is full.
iv. Strike off the surplus aggregates.
v. Determine the net weight of the aggregates to the nearest gram (W).
vi. Bring the impact machine to rest without wedging or packing up on the level plate, block or floor, so that it is rigid and the hammer guide columns are vertical.
vii. Fix the cup firmly in position on the base of machine and place whole of the test sample in it and compact by giving 25 gentle strokes with tamping rod.
viii. Raise the hammer until its lower face is 380 mm above the surface of aggregate sample in the cup and allow it to fall freely on the aggregate sample. Give 15 such blows at an interval of not less than one second between successive falls.

ix. Remove the crushed aggregate from the cup and sieve it through 2.36 mm IS sieves until no further significant amount passes in one minute. Weigh the fraction passing the sieve to an accuracy of 1 gm. Also, weigh the fraction retained in the sieve.

Compute the aggregate impact value. The mean of two observations, rounded to nearest whole number is reported as the Aggregate Impact Value.

Calculation:

Total weight of dry sample (W1 gm)

Weight of portion passing 2.36 mm sieve (W2 gm) Aggregate Impact

Value (percent) = W2 / W1 X 100

Recommended Value:

Aggregate Impact Value	**Classification**
<20%	Exceptionally Strong
10-20%	Strong
20-30%	Satisfactory for road
>35%	Weak for road surfacing

3.6 PROJECT KEY MILESTONES

NO	ACTIVITIES	JAN 2015				FEB 2014				MARCH 2015				APRIL 2015			
				W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
1	Collecting and analysis data																
2	Preparing Samples																
3	Lab testing work for aggregates																
4	FYP progress report submission																
5	Continue on lab work, and collecting and analyzing data																
6	Proposal Defense																
7	Submission of Interim Report																
8	Submission of Technical Paper																

Table 3.2: FYP 1
Grant Chart

NO	ACTIVITIES	MAY 2015				JUNE 2015				JULY 2015				AUGUST 2015			
				W1	**W2**	**W3**	**W4**	**W5**	**W6**	**W7**	**W8**	**W9**	**W10**	**W11**	**W12**	**W13**	**W14**
1	Lab work and Data gathering																
2	Poster Preparation																
3	Pre-SEDEX Presentation																
4	Preparation of Final Report Draft																
5	Submission of Final Report																
6	Preparation of Technical Report																
7	Submission of Technical Report																
8	Viva Presentation																
9	Completion of Dissertation																
10	Submission of Dissertation																

Table 3.3: FYP 2
Grant Chart

CHAPTER 4

RESULT AND DISCUSSION

4.1 INTRODUCTION

Bituminous mixes (sometimes called asphalt mixes) were used in the surface layer of road and airfield pavements. The mix was composed usually of aggregate and asphalt cements. Some types of bituminous mixes were also used in base course. The design of asphalt paving mix, as with the design of other engineering materials is largely a matter of selecting and proportioning constituent materials to obtain the desired properties in the finished pavement structure.

The desirable properties of Asphalt mixes are:

1. Resistance to permanent deformation: The mix should not distort or be displaced when subjected to traffic loads. The resistance to permanent deformation is more important at high temperatures.
2. Fatigue resistance: the mix property is important in cold regions.
3. Durability: the mix should contain sufficient asphalt cement to ensure an adequate film thickness around the aggregate particles. The compacted mix should not have very high air voids, which accelerates the aging process.
4. Resistance to moisture-induced damages.
5. Skid resistance.
6. Resistance to moisture-induced damage.
7. Workability: the mix must be capable of being placed and compacted with reasonable effort.
8. Low noise and good drainage properties: If the mix is to be used for the surface (wearing) layer of the pavement structure.

The result of aggregates test performed on ceramic samples were presented and discussed in this chapter. The samples were collected from waste/disposed ceramic tiles from construction site. The type of ceramic used were from domestic furnishing tiles and stoneware. There were several test conducted on the sample to determine highly on the strength of the samples and the porosity of the sample. Basically ceramics has low strength compared to conventional aggregate and high in water absorption due to more porosity within the sample. Thus, some test included were specific gravity and water absorption test, sieve analysis, Marshall Test and abrasion test. The result of the test will be shown in table and graph form which include in this chapter.

4.1.1 Specific gravity and water absorption test result

Specific gravity or density or water absorption of aggregates are the main properties that needed to design mixes in road construction. The density of an aggregate is the mass ratio equal to the volume of water that had been distilled at a certain temperature. The water-permeable voids may contain in the aggregates, therefore two measurements of density of aggregates are used: apparent specific gravity and bulk specific gravity.

4.1.2 Sieve Analysis

Sieve Analysis are used to grade accordingly the aggregate to its specific size. These size are then to compare with the standards that are used in construction to fulfil the needs of every behalf. The need of using standardizes grade is to ease on preparing the material, to inspect the structure after it finished and to reduce loss in cost by eliminating redundant aggregate size for a single batch. Sieve Analysis for coarse aggregate in this lab test are using pan from size 12mm to 63micron.

The results shows that the abundant ceramic waste come in every sizes and gradation are needed to achieved specific size for road construction. The upper limit will be crushed to allowed grade and lower limit will be removed by sieving.

4.1.3 Los Angeles Abrasion Test

The purpose of LA Abrasion test been carried out is to test the hardness of aggregates properties and to determine whether the aggregates are feasible to be used on construction of pavement layer. Los Angeles abrasion test is been standardized by BS812: Part 113:1990. The main focus of Los Angeles abrasion test is to find the percentage of wear due to relative rubbing action between the aggregate and steel balls use on this test. Los Angeles machine consist of circular barre with the diameter of 700mm and the length of 520 mm attached on horizontally to enable it to be rotated. An abrasive charge consist of steel round balls with a diameter of 48 mm and weighing 340-445 g was placed in the barrel along with the aggregates. The numbers of the abrasive steel balls used are difference depending on the gradation and normal it ranges between 5-10 kg. The barrel is then locked and rotated at the speed of 30 rpm for a total of 500 revolutions.

After completed the 500 revolutions of rotation, the aggregate is sieved through 1.7 mm sieve and the weight of passing aggregates are taken. This value is called Los Angeles abrasion value. For bituminous concrete, a maximum value of 40 is specified.

This test was conducted according to ASTM C131 standard method. Figure 4.1 shows the result of the Los Angeles test, where the L.A. abrasion loss value in percentage has been shown. As can be seen, the all recycled aggregates have a higher abrasion value compared to the normal aggregate. The results for Los Angeles Abrasion value is 21.6% greater than that for the conventional without substitution which is only 11%.

4.1.4 Marshall Test

In this method, the resistance to plastic deformation of a compacted cylindrical specimen of bituminous mixture is measured when the specimen is loaded diametrically at a deformation rate of 50 mm per minute. There are two major features of the Marshall method of mic design.

1. Density void analysis
2. Stability flow test

The Marshall stability of the mix is defined as the maximum load carried by the specimen at a standard test temperature of 60°C. The flow value is the deformation that the specimen undergoes during loading up to the maximum load. Flow is measure in 0.25 mm units. In this test, an attempt is made to obtain optimum binder content for the type of aggregate mix used and the expected traffic intensity.

4.1.5 Flakiness Index

The flakiness and elongation indexes tests on RCW and NA were conducted according to British Standard. The results are as shown in Table 4.3. The values of flakiness and elongation indexes of all the RCW samples are lower compared to the value of natural aggregate. Thus, the RCW is flakier than NA and this will reduce the workability of pavement mixture that use the RCW.

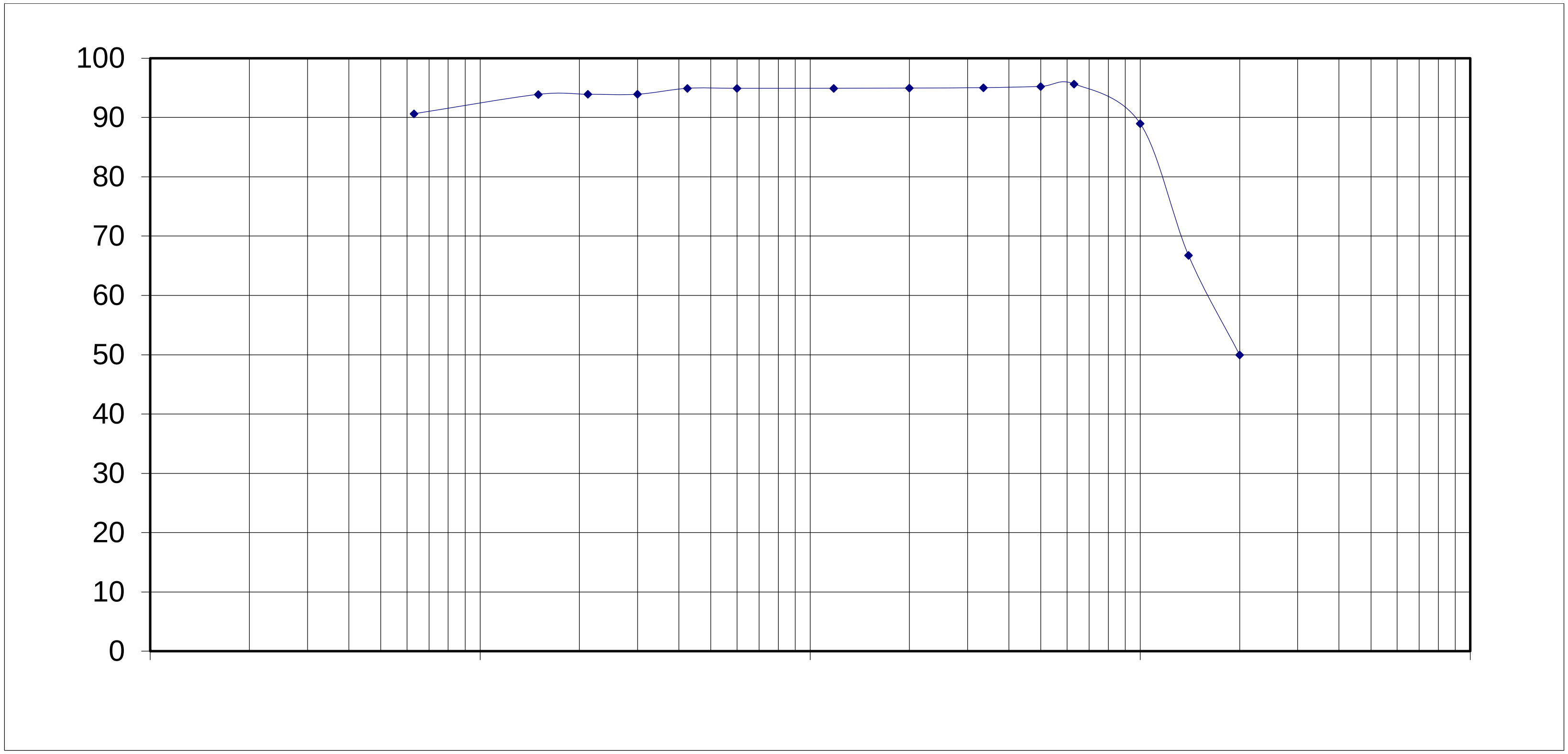
4.2 RESULTS

4.2.1 Sieve Analysis

Sieve Analysis test shows that the ceramic sample present in abundant can't be directly mix with the pavement material to replace conventional aggregate. It need to gone through several grinding process to reduce the size of the aggregate and to get optimum size to match with the JKR Standard for Road Construction.

Table 4.1: Sieve Analysis for Sample 1

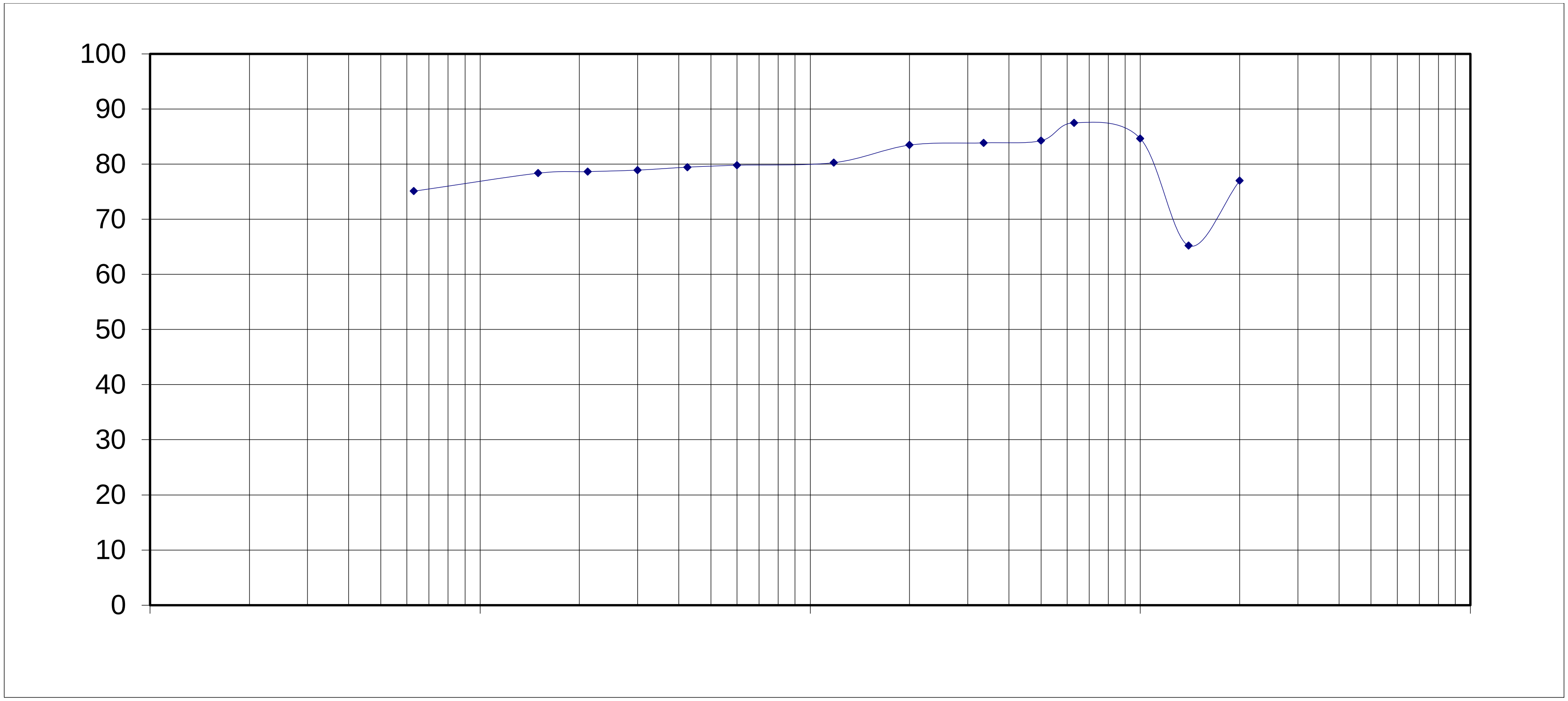
Project: The Use of Ceramic as a Substitute for Aggregate		Job ref.		
		Borehole / Pit No:.		
Soil Decription Sample 1		Sample no.	Ceramic	
		Time:.		
		Date of sample		
Test Method BS 1377:Part2:1990:**9.2/9.3/9.4**		Date of Tested:	1/5/2015	
Initial Dry mass **m_1**	2000	g		
BS Test Sieve mm	Mass Retained (g)		Percentage retained	Cumulative percentage Passing
	actual	corrected m	(m/m1)100	
20	1000.6	1000.60	50.03	49.97
14	664.6	664.60	33.23	66.77
10	220.4	220.40	11.02	88.98
6.30	86.600	86.60	4.33	95.67
5.00	8.300	94.90	4.75	95.26
3.35	4.400	99.30	4.97	95.04
2.00	1.300	100.60	5.03	94.97
1.18	0.700	101.30	5.07	94.94
0.600	0.100	101.40	5.07	94.93
0.425	0.000	101.40	5.07	94.93
0.300	20.100	121.50	6.08	93.93
0.212	0.100	121.60	6.08	93.92
0.150	0.200	121.80	6.09	93.91
0.063	65.440	187.24	9.36	90.64
Passing 0.063 m_F or m_E	22.410			
Total (check with **m_6**)	2095.250		**m_1**	
		Operator	Checked	Approved



Graph 4.1: PSD for Sample 1

Project: The Use of Ceramic as a Substitute for Aggregate			Job ref.	
			Borehole /	
			Pit No:.	
Soil Description Sample 2			Sample no.	Ceramic
			Time:	
			Date of sample	
Test Method BS 1377:Part2:1990:**9.2/9.3/9.4**			Date of Tested:	1/5/2015
Initial Dry mass **m_1**	2000		g	
BS Test Sieve mm	Mass Retained (g)		Percentage retained	Cumulative percentage Passing
	actual	corrected m	(m/m1)100	
20	460.1	460.10	23.01	77.00
14	695.6	695.60	34.78	65.22
10	307.2	307.20	15.36	84.64
6.30	250.1	250.10	12.51	87.50
5.00	64.9	315.00	15.75	84.25
3.35	7.8	322.80	16.14	83.86
2.00	8	330.80	16.54	83.46
1.18	63.9	394.70	19.74	80.27
0.600	9.3	404.00	20.20	79.80
0.425	7	411.00	20.55	79.45
0.300	10.7	421.70	21.09	78.92
0.212	5.5	427.20	21.36	78.64
0.150	5.6	432.80	21.64	78.36
0.063	65.440	498.24	24.91	75.09
Passing 0.063 m_F or m_E	22.410			
Total (check with **m_6**)	1983.550		**m_1**	
		Operator	Checked	Approved

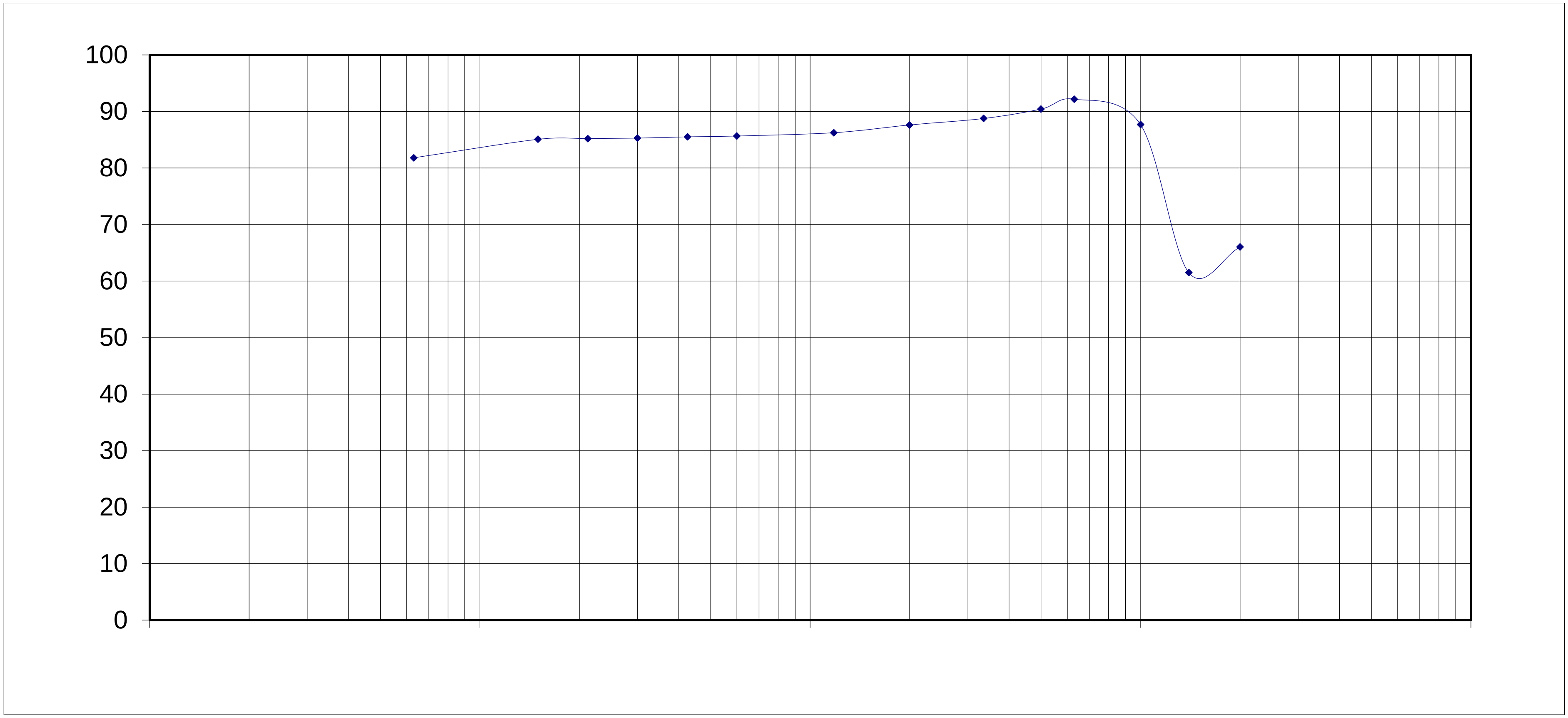
Table 4.2: Sieve Analysis for Sample 2



Graph 4.2: PSD for Sample 2

Project: The Use of Ceramic as a Substitute for Aggregate		Job ref.		
		Borehole / Pit No:.		
Soil Description Sample 3		Sample no.	Ceramic	
		Time:.		
		Date of sample		
Test Method BS 1377:Part2:1990:**9.2/9.3/9.4**		Date of Tested:	1/5/2015	
Initial Dry mass **m_1**	2000	g		
BS Test Sieve mm	Mass Retained (g)		Percentage retained	Cumulative percentage Passing
	actual	corrected m	(m/m1)100	
20	679.7	679.70	33.99	66.02
14	770.2	770.20	38.51	61.49
10	246.5	246.50	12.33	87.68
6.30	156.3	156.30	7.82	92.19
5.00	35	191.30	9.57	90.44
3.35	33.4	224.70	11.24	88.77
2.00	22.9	247.60	12.38	87.62
1.18	27.4	275.00	13.75	86.25
0.600	11.7	286.70	14.34	85.67
0.425	2.9	289.60	14.48	85.52
0.300	4.5	294.10	14.71	85.30
0.212	1.9	296.00	14.80	85.20
0.150	2.4	298.40	14.92	85.08
0.063	65.440	363.84	18.19	81.81
Passing 0.063 — m_F or m_E	22.410			
Total (check with **m_6**)	2082.650		**m_1**	
		Operator	Checked	Approved

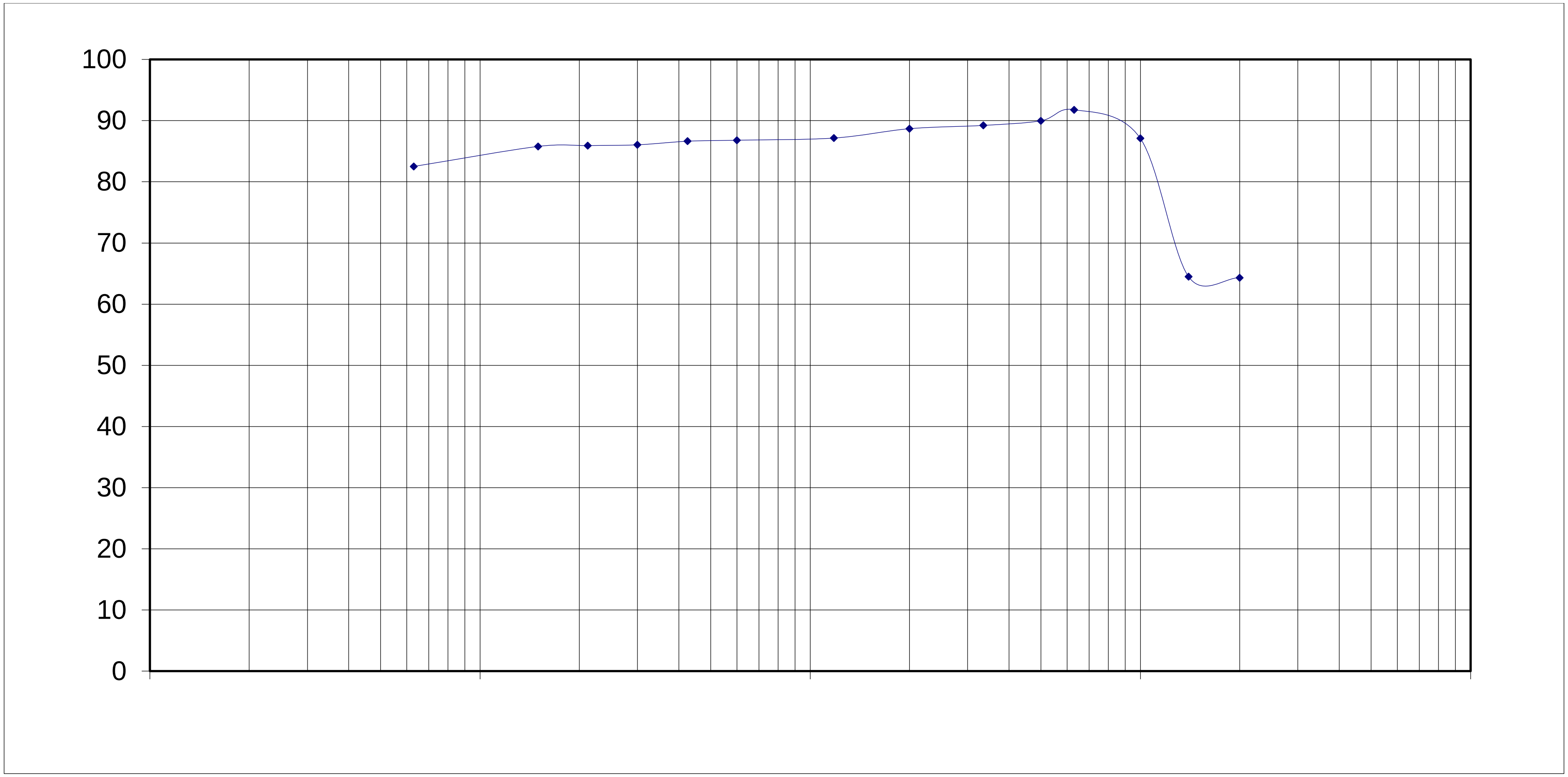
Table 4.3: Sieve Analysis for Sample 3



Graph 4.3: PSD for Sample 3

Project:	The Use of Ceramic as a Substitute for Aggregate		Job ref.		
			Borehole /		
			Pit No:.		
Soil Description	Average		Sample no.		Ceramic
			Time:.		
			Date of sample		
Test Method BS 1377:Part2:1990:**9.2/9.3/9.4**			Date of Tested:		1/5/2015
Initial Dry mass **m_1**		2000	g		
BS Test Sieve mm		Mass Retained (g)		Percentage retained	Cumulative percentage Passing
		actual	corrected m	(m/m1)100	
20		713.4666667	713.47	35.67	64.33
14		710.1333333	710.13	35.51	64.49
10		258.0333333	258.03	12.90	87.10
6.30		164.3333333	164.33	8.22	91.78
5.00		36.06666667	200.40	10.02	89.98
3.35		15.2	215.60	10.78	89.22
2.00		10.73333333	226.33	11.32	88.68
1.18		30.66666667	257.00	12.85	87.15
0.600		7.033333333	264.03	13.20	86.80
0.425		3.3	267.33	13.37	86.63
0.300		11.76666667	279.10	13.96	86.05
0.212		2.5	281.60	14.08	85.92
0.150		2.733333333	284.33	14.22	85.78
0.063		65.44	349.77	17.49	82.51
Passing 0.063	m_F or m_E	22.41			
Total (check with **m_6**)		2053.817		**m_1**	
			Operator	Checked	Approved

Table 4.4: Sieve Analysis for Average Sample



Graph 4.4: PSD for Average Sample

4.2.2 Los Abrasion Test

The test shows that the sample is still below the minimum limit for the sample to degrade during operation and under traffic load. The ceramic sample still pass the wearing percentage which limit which is 40% of total mass is reduced due to wearing process.

Initial Weight (g)	Dust Weight (g)	Final weight (g)	Percentage of abrasion
5000	1082.3	3917.7	21.646

Table 4.5: Los Abrasion result

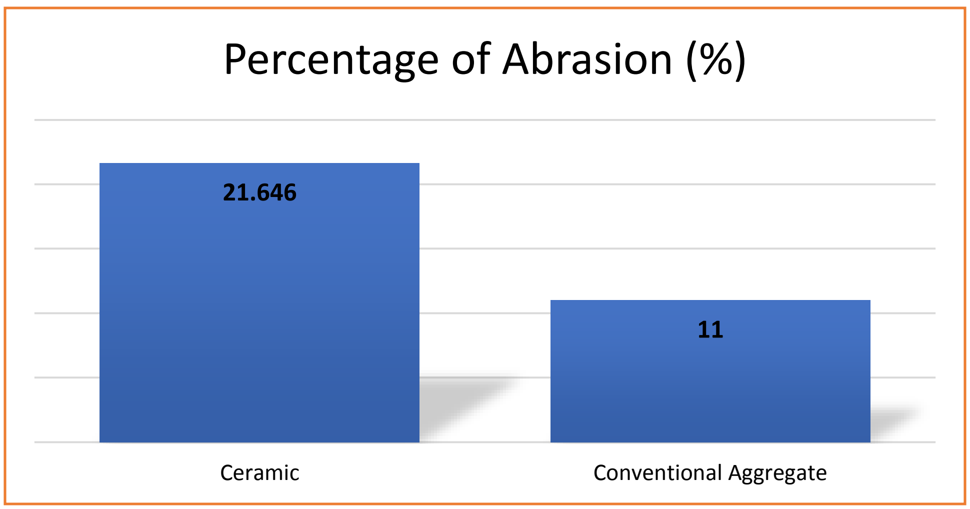


Chart 4.1: Percentage of Abrasion Chart

4.2.3 **Specific Gravity**

It shows that the void content in the ceramic sample are significantly higher than conventional aggregate which help to increase the porosity of the sample.

Specific Gravity	Empty	Dry	Added with Water	Water Only	Empty
Sample 1	544.4	1485.3	2117.2	1566.9	390.5
Sample 2	536.3	1540.8	2150.6	1529	391.7
Sample 3	536.9	1414	2071.6	1561	391.7

Oven Dry		
	Empty	With Sample
Pan 1	71.1	1076.7
Pan 2	72.5	1150
Pan 3	66.4	1007.5

Table 4.6: Specific Gravity Results

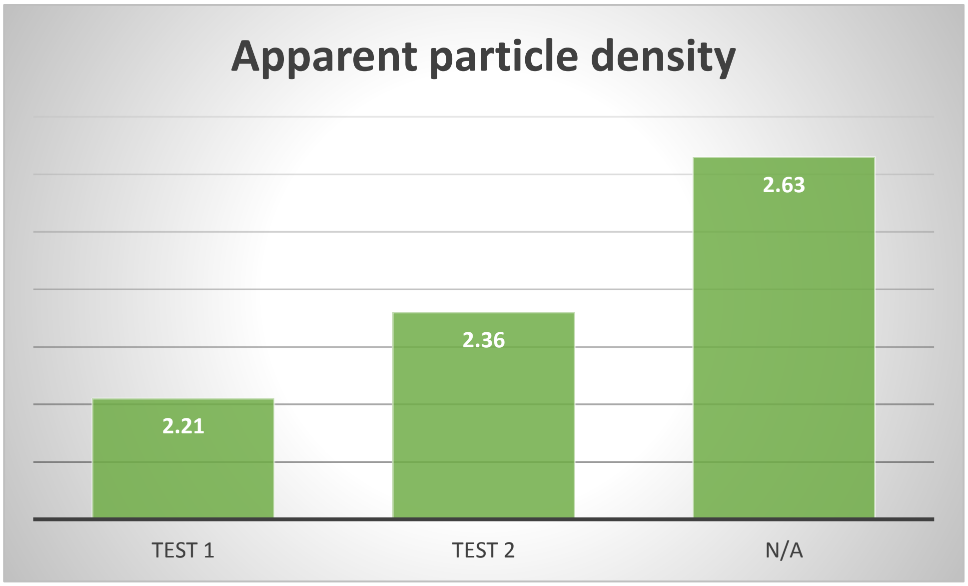


Chart 4.2: Apparent Particle Density

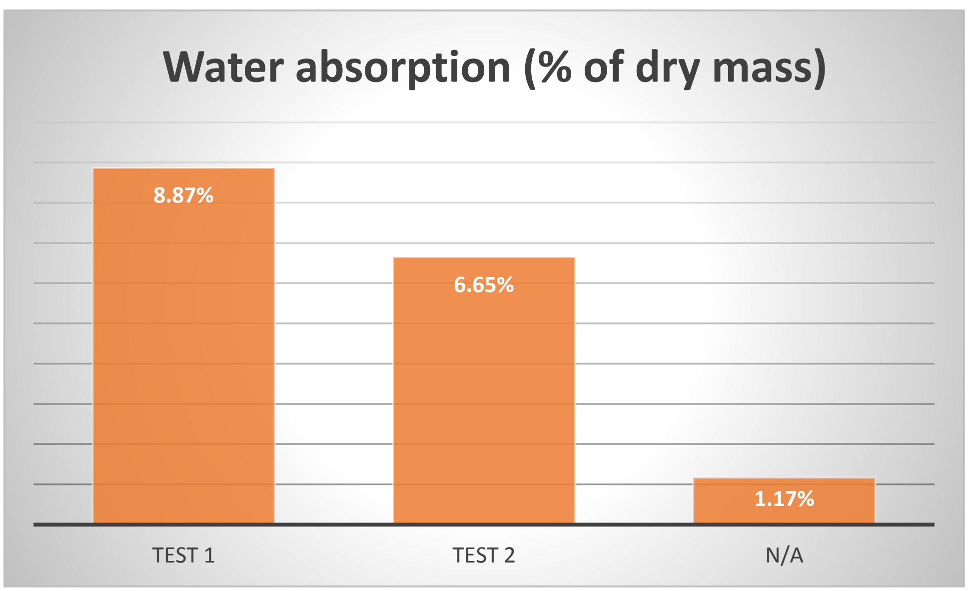


Chart 4.2: Water Absorption (% dry mass)

4.2.4 Marshall Test

Marshall Test shows that the graph is still under limitation of JKR Standard which means that the material still can used with the conventional aggregate with certain proportion that allows the properties of the ceramic can be imply in the mixture with losing its strength. From the test conducted, it shows that the Optimum Bitumen Content (OBC) is on the 5%.

Figure 4.1: Sample under Marshall Test

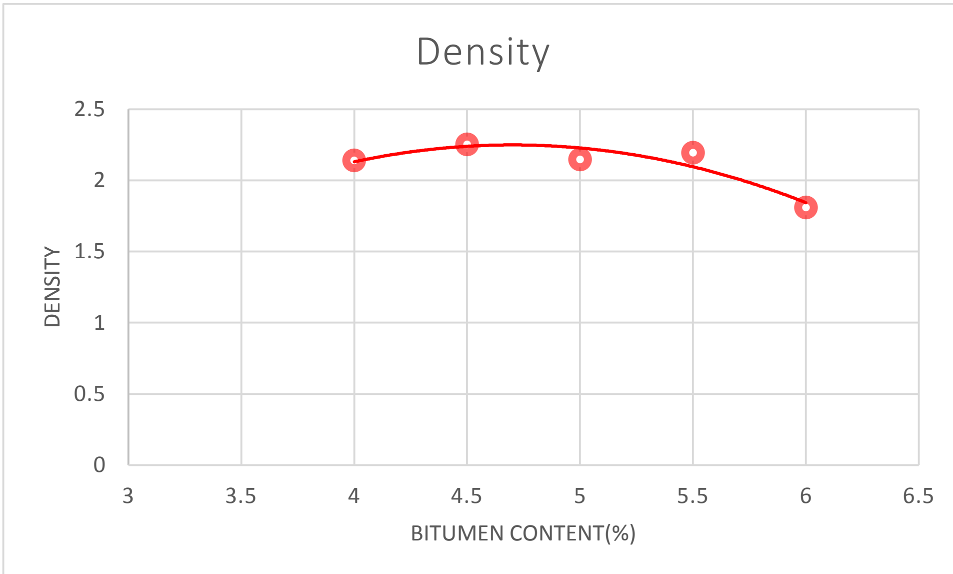
Figure 4.2: Preparing of Marshall Sample

Sample	Binder Content(%)	Height(mm)	Mass of Specimen		Density	Sgmix	Porosity	Flow(mm)	Stability(kN)	Actual MS	
			In air(g)	In water(g)						Correction Factor	Actual(kN)
1	4	79.27	1267.7	660.6	2.088123868	2.499592009	16.46141209	1.48	2.4	0.96	2.304
2		77.92	1274.8	685.8	2.16434635	2.499592009	13.41201516	2.16	2.8	0.96	2.688
3		78.1	1271.4	684	2.164453524	2.499592009	13.40772749	2.16	3.4	0.96	3.264
4	5	78.22	1264.1	660.6	2.094614747	2.464429811	15.00611063	2.95	3.8	0.96	3.648
5		85.43	1391.6	745	2.152180637	2.464429811	12.67024009	4.76	4.2	0.96	4.032
6		83.81	1369.6	745	2.192763369	2.464429811	11.02350091	3.4	3.85	0.96	3.696
7	6	76.1	1268.8	688	2.184573003	2.430910912	10.13356384	1.45	5.42	0.96	5.2032
8		75.7	12540	683.2	1.057620943	2.430910912	56.49281354	2.41	5.5	0.96	5.28
9		77.6	1283.4	695.6	2.183395713	2.430910912	10.18199384	2.95	8.12	0.96	7.7952
10	4.5	74	1253.7	694.4	2.24155194	2.481798036	9.680324217	3.46	6.95	0.96	6.672
11		75.05	1267.6	708	2.265189421	2.481798036	8.727890508	2.85	7.55	0.96	7.248
12		74.38	1264	701.1	2.245514301	2.481798036	9.520667349	3.65	10.86	0.96	10.4256
13	5.5	76.22	1267.1	687.2	2.185031902	2.447472234	10.72291357	2.27	4.61	0.96	4.4256
14		76.4	1256.9	685	2.197761846	2.447472234	10.20278736	1.92	3.52	0.96	3.3792
15		76.2	1274.6	694.6	2.197586207	2.447472234	10.20996373	2.51	4.18	0.96	4.0128

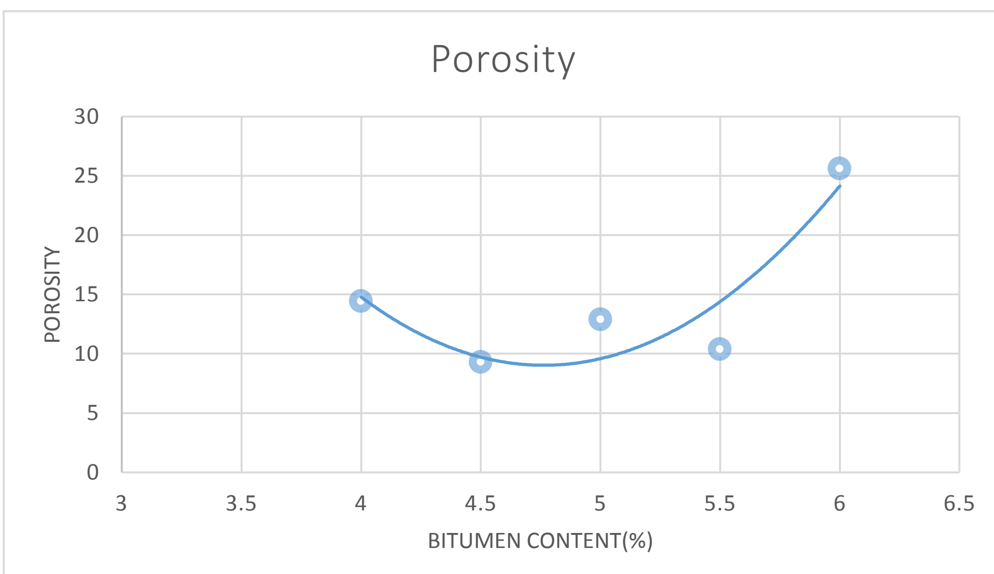
Table 4.7: Masrshall Test Result

Binder Content(%)	Density	Porosity	Flow	Marshall Stability	Actual Marshall Stability
4	2.13897458	14.42705	1.933333333	2.866666667	2.752
5	2.146519584	12.89995	3.703333333	3.95	3.792
6	1.808529886	25.60279	2.27	6.346666667	6.0928
4.5	2.250751887	9.309627	3.32	8.453333333	8.1152
5.5	2.193459985	10.37855	2.233333333	4.103333333	3.9392

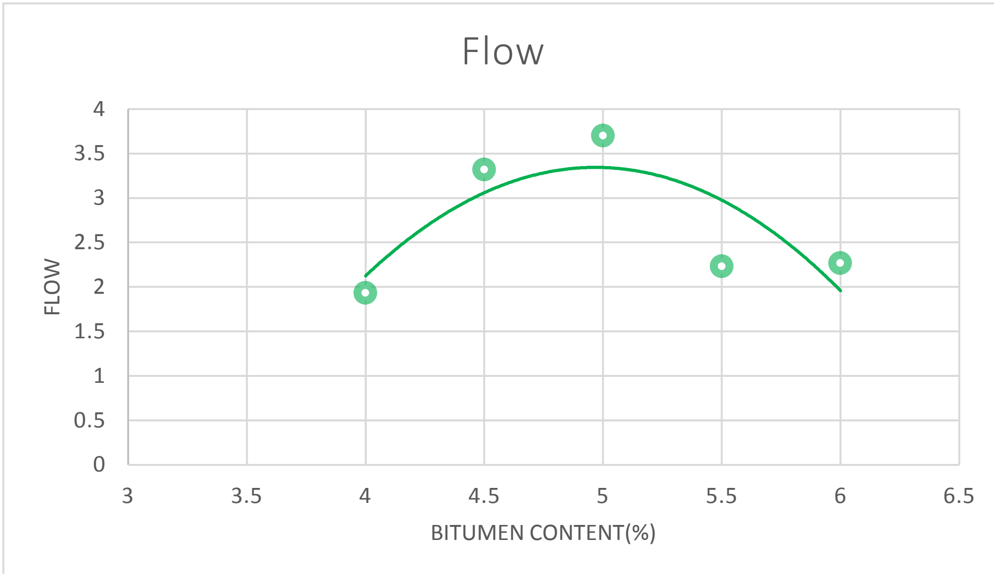
Table 4.8: Marshall Test Result



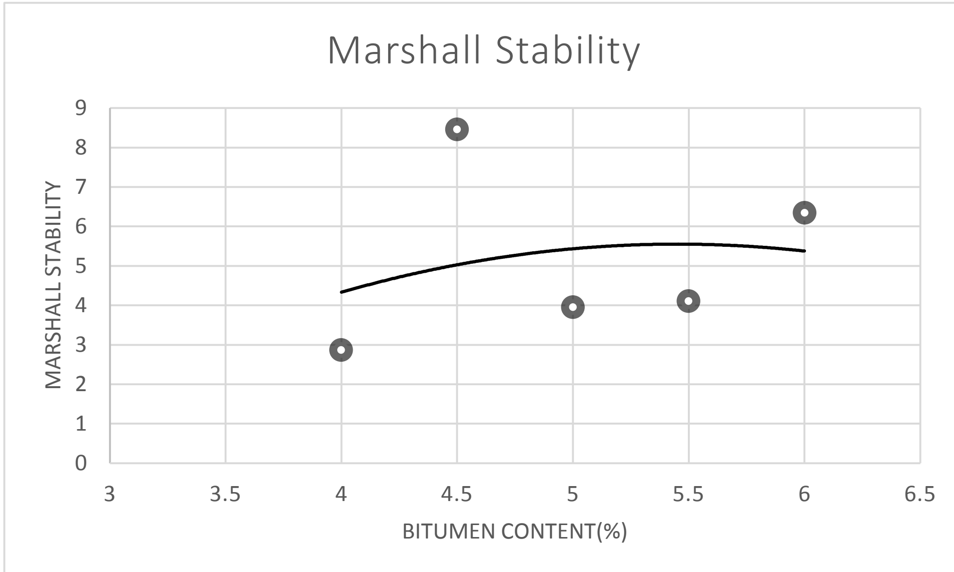
Graph 4.5: Density Vs Bitumen Content



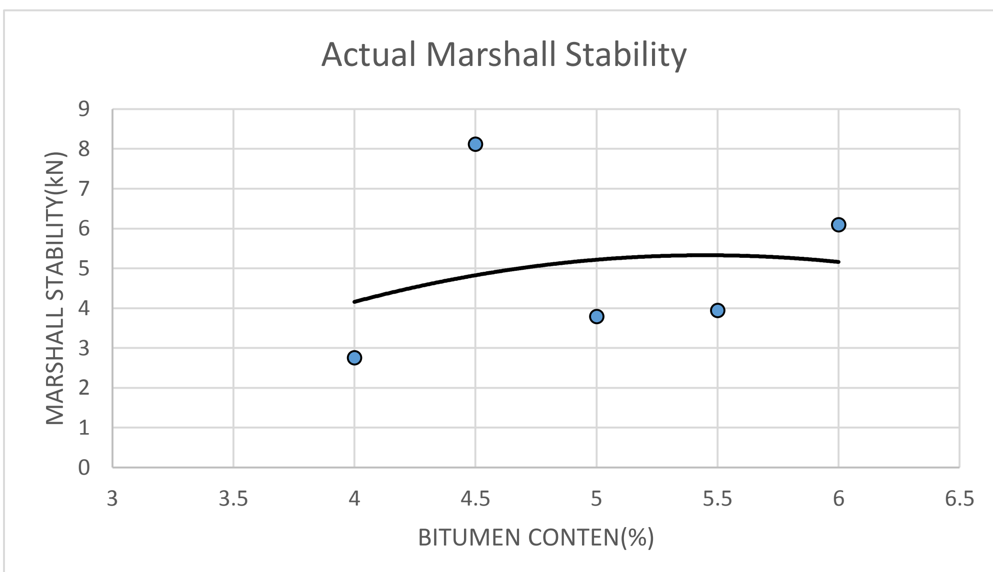
Graph 4.6: Porosity Vs Bitumen Content



Graph 4.7: Flow Vs Bitumen Content



Graph 4.8: Marshall Stability Vs Bitumen Content



Graph 4.9: Actual Marshall Stability Vs Bitumen Content

4.2.5 Flakiness Index

The overall results of RCW flakiness index are lower than 25% where according to the JKR standard it is suitable to be used for construction of road pavement. This means that RCW is suitable to be used as coarse aggregate in road construction.

Samples	Flakiness Index (%)	Elongation Index (%)
RCW-1	38.4	11.50
RCW-2	21.50	12.0
RCW-3	22.4	13.00
NA	38.33	39.10

Table 4.7: Result for Elongation & Flakiness

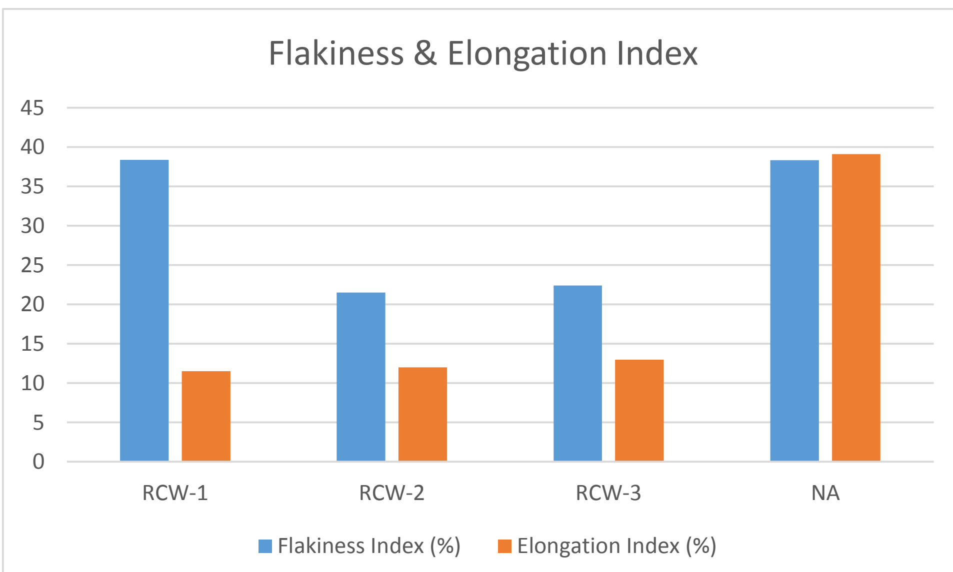


Chart 4.3: Flakiness & Elongation Index

CHAPTER 5

CONCLUSION & RECOMENDATION

Further test require to pin-point the exact quantity and measurement to get optimum percentage of Ceramic to be used to be replaced with the conventional aggregate. This is to determine the exact data that are which are more consistent and reliable. Approval from other researches to justify the competency of the ceramic used in the conventional aggregate is also indeed needed to fulfil the need to achieve of better application of this method.

Variation of percentage of ceramic used as the sample should be conduct to determine the prefect mixture. Sample should be cover all type of ceramic which present abundantly in the disposal site. Higher chance of getting precise data if we approach this manner as we can see and learn what type of ceramic can be obtain in vast amount that need to be used in road construction.

Besides that, I also need to tackle the strength that those ceramic have. Different type of ceramic has different component in their matrix that make them different in strength. Higher mineral make up higher strength which are physically tough. But, it is really hard to get to this type of ceramic due to its rarity.

Even though 30% of ceramic is used to substitute with the conventional aggregate are having quite small reading with the constant one, but I also need to find its effectiveness in term of economic value. Does implication of these are effective and efficient in those country. Did, this really help theme to reduce the total garbage collected daily? And will it trigger economic boom to the country, introduce new field in construction. The answers will have to wait for the next detailed research.

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